A PROJECTION OF THE GROWTH IN NETWORKS AND SYSTEMS AT S.G.W.U.

1. Graduate Education in Engineering and its role in the Canadian Economy:

Graduate work in engineering is a result of the explosive growth in Science within the last thirty years. At the end of World War II, engineers became painfully aware that only with difficulty could they understand and apply the latest advances in the pure sciences, and that they could no longer contribute to the progress of research in the applied sciences.

Intensive efforts were made to improve the professional qualifications of engineers. Within larger industries, the more qualified members of the engineering staff were called upon to begin "in-plant" training programmes for their colleagues. Arrangements were made with local universities to provide either extension courses or part-time programmes leading to advanced degrees. Finally, full time graduate schools were established. With government support, these grew rapidly until they could provide the qualified personnel needed for the progress of technology.

Canada has lagged considerably behind the United States in all aspects of engineering education. Table I shows the relative positions in technical man power in three countries(1). Although this data is for the year 1963, the relative positions are probably unaltered.

TABLE I

TECHNICAL MANPOWER IN 1963

Country	Engineers and Physical Scientists per 10,000 population.
Canada	48.9
United States	61.7
Sweden	63.5

If Canada lags so far behind in terms of engineers in general, what must be the situation in other aspects of engineering education. In-plant training programmes are virtually non-existent, and it is a little over a year since Sir George Williams University became the first University in Quebec to initiate a part-time master's degree programme in engineering. The situation at the doctoral level is well summarized in the 1969 report of the Science Council of Canada to the Prime Minister(2).

"Recent Statements in the press suggesting a potential over-supply of Ph.D's have in our view tended to misinterpret the true state of affairs. The large investments that Canada has been making in post secondary education are now just beginning to pay dividends. Inevitably there will be temporary surplusses and shortages in specific disciplines, following from previous policies, but over all there will be a continuing deficit for many years as we seek to raise the educational quality of our labour force towards that of the USA, a process which the Economic Council has suggested is an important prerequisite if we are to

close the productivity gap. As the supply improves at the higher educational levels, the patterns of use in Canada will change. Ph.D's must move in greater numbers into engineering, management, industrial Research and Development, secondary school and technological institute teaching, and many other areas where their talents are needed. We must also reduce our heavy dependence on non-Canadians to fill new University and College positions. As we see it, the supply will be no more than sufficient to support the build-up in scientific and technological activities that we are recommending in the coming years. To reduce the transient difficulties of disciplinary mismatch between supply and demand, a clearly stated and continuing policy of support for specific Research and Development programmes is important. This will encourage students to enter the professional specialities in which demand exists or can be expected".

Therefore, at the present, it is unrealistic to worry about having an overabundance of Canadian Ph.D's in engineering. The question is not whether we have too many Ph.D's, but rather how we can increase the present number.

2. System Theory:

System theory is one of the fundamental disciplines of the engineering profession. In the broadest sense, a system may be defined as an interconnection of elements acting upon a set of inputs to produce a desired set of outputs. For example, in a chemical plant, the various raw materials used can be considered

as inputs, the individual processors as elements, and the synthesized compounds as outputs. In the production of a particular compound, it is necessary to control the performance of the overall system. Various parameters, such as temperatures, flow rates, densities, etc., are continually monitored and used as inputs to a subsystem whose function is to alter the process in some optimum way.

System theory may be defined as the ensemble of techniques for analyzing, simulating and synthesizing systems and subsystems. The system theorist will to some extent ignore the physical or chemical phenomena involved in a given system, and will be more interested in studying the interaction of devices having certain characteristics. System theory, therefore, is a general approach which can be applied to the study of models having mathematically similar characteristics independent of their physical origin. Thus an engineer who is well grounded in the principles of system theory has at hand tools which can be effectively applied to a wide variety of engineering prlblems.

3. Graduate Study in Network Theory:

Systems Theory is one of the major areas of specialization in the faculty of engineering at this University. Because of the scope of the subject, it cannot be restricted to any one of the formal disciplines of engineering (electrical, mechanical, etc). Thus faculty members belonging to different departments may specialize in one or another aspect of the subject.

Our particular areas of interest include the analysis and synthesis of linear electrical networks, and the computer simulation of a wide class of physical systems. The study of electrical networks is as old as electrical engineering itself. Since the middle of the last decade, academic involvement has grown considerably and several large American universities have developed major programs in network theory. A partial listing of these could include Stanford University, Cornell, Syracuse, New York State University, City College of New York, Berkeley, University of Florida, Texas Technological College, and Colorado State University. In addition, some major electronics industries, for example, Bell Laboratories, have set up research groups to pursue particular aspects of network theory.

"One reason for this is that electrical network theory is essentially the theory of linear systems and hence finds application in numerous fields other than that in which it originated and grew to its present state of respectability. A second reason of no less significance is owing to the importance of linear passive network theory as a tool in dealing with a broader class of network problems defined by the adjectives: nonpassive, nonbilateral, nonlinear, and statistical. Practically all that we know how to accomplish in these areas at present is based upon a manipulative procedure so chosen that linear, passive bilateral theory again becomes applicable."

"These facts are both good and bad for the state of network theory. They are good because network theory, being an

essential tool in a very broad field of engineering activity, attracts the attention of many more individuals than merely those who specialize in it for its own sake. They are bad because the mere 'users' of network theory are satisfied with a very superficial understanding of it. They are interested primarily in learning 'how things go', and are content with only a smattering knowledge (sic) of 'why things are that way'. They do not realize that even a tool must be well understood to be most useful, and that it can betray the unwary who misuse it." (3)

The last part of the above statement is in fact a summary of the state of affairs in Canada. In many Canadian industries, electrical circuit design is more a matter of art than science, the use computer-aided design programs is not properly understood, and new techniques often cannot be introduced until American competitors have made these standard practice.

Until five years ago, graduate work in electrical network theory was almost nonexistent in Canada, and is only now being introduced in a few universities. McGill has an internationally recognized specialist in computer-aided network design. The Universities of Waterloo and Calgary are presently making serious efforts to establish groups in systems and networks. McMaster University and the University of New Brunswick established groups in systems with emphasis on control theory. So far, there has been no overlap in areas of specialization.

4. Graduate Study in Network Theory and Systems Simulation at S.G.W.U.

4.1 Faculty of Involvement

At S.G.W.U. approval has been given by the Board of Graduate Studies to the Faculty of Engineering to initiate research and graduate work in Networks and Systems, including studies at the doctoral level. The Faculty of Engineering has, at present, three specialists in Networks and four members in Systems. The Department of Electrical Engineering also has a specialist in microelectronic technology. An additional faculty member joining in 1970 will also be in the area of Networks. It is hoped that we can attract the person who formerly worked with some of the members of this research team. The qualifications and current research interests of the members of this group are described in Appendices A and B.

4.2 Master of Engineering Program

At present, a master's degree in engineering may be obtained on a part time basis only, and with few exceptions, candidates for this degree are engineers employed by various industries in the Montreal area. Although this program provides an invaluable service to the industrial community, it cannot effectively contribute to the growth of research within the university. Technology is changing so rapidly, and competition is so intense that only individuals who are engaged almost exclusively in research activities can make significant and timely contributions to the engineering science. This is particularly true at the doctoral level where "significant"

and "timely" contributions are a must.

4.3 The Doctoral Student as a member of a research group

The doctoral student is an integral part of an university research group. Faculty members usually have several projects which they would like to undertake but cannot for lack of time, whereas the student, once he has completed his course work can devote his full time to research. Further, the student is expected to have ideas of his own, to think of new methods of attacking problems, to interpret his results, and to discuss matters not only with his guide but with other members of group as well. It is, in fact, this continuing interaction among like-minded individuals which enables each member of a research group to be far more productive than he could be alone.

5. Projected Growth of the Graduate Program over the Next Five Years:

To arrive at a realistic assessment of the optimum growth rate of the graduate program in Networks and Systems the following factors are considered:

1. The approved faculty strengh of nine members in this area for the fall of 1970.

2. Each faculty member should, on the average, be guiding three doctoral students. Experience has shown that doctoral candidates with a master's degree require two to three years to complete the program. In the first phase, the candidate will devote most of his time to course work. It is during the second phase, when he is being initiated into the research work that

he requires the closest supervision. In the third phase, when he is finishing his work and preparing his thesis he is expected to be largely independent. Hence the guide would be intimately involved with but one doctoral student at a time. Therefore, each faculty member would have one graduating doctoral student per year.

3. The full complement of graduate courses in Networks will soon be submitted to the E.G.S.C. for approval. Policies concerning the general examinations have also been formulated. The first such examination was recently held. The candidate, Mr. P.K.Verma, is now preparing his thesis.

4. Students pursuing a master's degree program on a part time basis will require two to three years. During the great majority of this time, the supervisor will act purely in an advisory capacity. Thus it is thought that each faculty member may easily guide five master's students.

5. At this time, it is assumed that master's students are financially self-supporting. In addition, no capital expenditures in the area are foreseen in the next five years. Based on current N.R.C. grants awarded to faculty members who are and who will be members of the Networks and Systems group, it will be possible to supply adequate financial assistance to the number of doctoral students envisioned in Table 2 below.

The following tables summarize the above considerations.

Table 2 - Projected Growth of Graduate Programme

Year	MASTER'S STUDENTS		DOCTORAL STUDENTS		RESEARCH ASSOCIATES	
	Networks	Systems	Networks	Systems	Networks	Systems
69/70	10	6	4	0	0	0
70/71	20	20	9	8	1	0
71/72	20	20	12	12	1	1
72/73	20	20	12	12	2	2
73/74	20	20	12	12	2	2

Table 3 - Anticipated Income from N.R.C.*

Anticipated Grants	Networks	Systems
April 1, 1968 (previous year)	$ 24,500	$ 0
April 1, 1969 (present)	32,000	0
April 1, 1970	45,000	30,000
April 1, 1971	50,000	45,000
April 1, 1972	55,000	50,000
April 1, 1973	60,000	55,000
	$266,500	$180,000

*These figures are based on the current or previous grants awarded to faculty members who are or will probably be members of the Networks and Systems group as of September, 1970.

Table 4 - Anticipated Cost of Supporting Doctoral Students and Research Associates*

The following figures are based on the N.R.C. maximum rate of $3,000 per annum per student and $7,000 per annum per research associate. Master's candidates are self-supporting.

YEAR	NETWORKS	SYSTEMS
70/71	$ 34,000	$ 24,000
71/72	43,000	43,000
72/73	50,000	50,000
73/74	50,000	50,000
	$177,000	$167,000

*Students accepted in the doctoral program before April 1, 1970, can be supported from current N.R.C. grants.

In the year 1970-71, the number of full-time equivalent graduate students may appear as shown in Table 5.

6. Conclusion

Sir George Williams University now has an excellent opportunity to make a major contribution in a particularly fertile field of applied science. Moreover, we emphasize that although the number of doctoral students requested in the area of Networks and Systems is several times larger than the total present allotment to the faculty of engineering, the increase in cost to the university will be minimal since,

- No additional faculty is asked for beyond what has been already approved.

- No financial support by the university for these

Table 5 - Maximum Faculty Load for 1970-71

	M.Eng. (Full-time equivalent)***	D.Eng.
1. *M.N.S. Swamy	2	3
2. *V. Ramachandran	2	3
3. W. Jaworski	2	3
4. B. Lombos	3	2
5. V. Panuska	3	2
6. G.S. Mueller	4	1
7. J.C. Giguere	3	1
8. A. Tari	3	-
9.**B.B. Bhattacharyya	3	2
	25	17

(These represent,for the group, an upper limit.)

* These faculty members have guided and are continuing to guide doctoral students.

** It is anticipated that Dr. B.B. Bhattacharyya will be joining the gorup by July 1970.

***A part time Master's student is assumed at any given time to be equivalent to one-half the load of a full time student.

doctoral students is being requested.

- No capital expenditures in terms of laboratory space and equipment are required.

The sole cost to the university will be in providing sixty square feet of floor space and a desk for each student.

This is surely a small outlay considering the benefits which will accrue both to the university and to the community.

REFERENCES

1. "National Objectives for Canadian Science and Technology as suggested by the Engineering Institute of Canada," June 6, 1969, p. 43.
2. Science Council of Canada, Third Annual Report, June 1969, pp. 33-34.
3. E. Guillemin, Synthesis of Passive Networks, John Wiley and Sons, 1957, pp. vii, viii.

APPENDIX "A"

			Publications	Patents	Guidance of Students	NRC GRANT (Current)
M.N.S. Swamy	Ph.D. (Saskatchawan	1963	50	-	2 Ph.D. 5 M.Eng.	$ 15,000
V. Ramachandran	Ph.D. (Indian Institute of Science)	1965	35	-	1 Ph.D. 5 M.Eng.	10,000
W. Jaworski	Ph.D. (Warshaw)	1957	55	1	12 M.Eng.	-
B. Lombos	Ph.D. (U.of Montreal)	1966	12	2	-	-
V. Panuska	D.Phil. (Oxford University)	1969	9	1	-	-
G.S. Mueller	Ph.D. (Manchester)	1969	1	-	-	-
J.C. Giguere	Ph.D. (NSTC)	1969	10	2	-	3,700
A.I. Tari	D.Sc. (Paris)	1965	-	-	6	-
B.B. Bhattacharyya	Ph.D. (NSTC)	1968	25	-	-	7,000

APPENDIX "B"

Topics of Specialization of the Networks and Systems Group at S.G.W.U.:

1. The analysis or synthesis of distributed parameter networks and their application in the design of microelectronic circuitry.
2. The synthesis of "lumped" linear networks.
3. The sensitivity of the response of a linear network as a result of variations in the parameters of its constituent parts with the ultimate goal of determining synthesis techniques which will minimize this sensitivity.
4. The simulation of physical systems.
5. Development of computational algorithms for system identification and control. (The Faculty has acquired for this purpose an EAI 690 Hybrid Computer System.)